Mechanism of Stomatal Transpiration

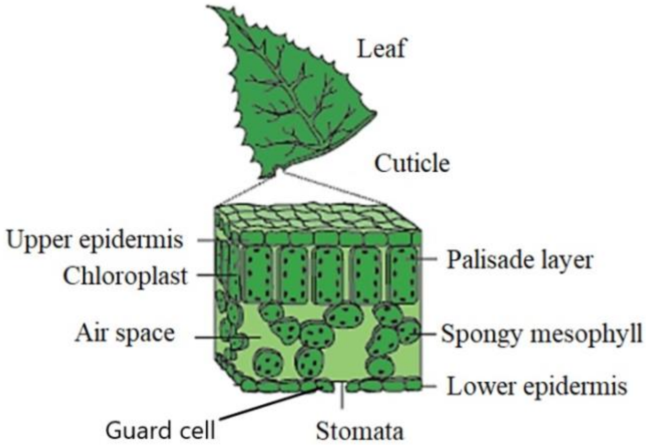
Stomatal Transpiration in short

1. ***The water from the xylem of the leaves move to the intercellular space in the parenchyma tissue above the stomata.***

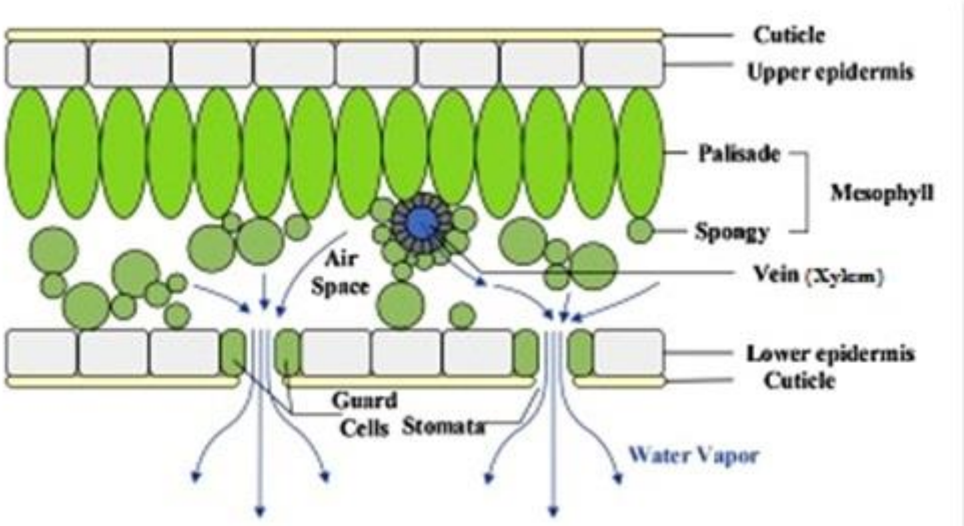
2. ***Water moves inside the guard cells***

3. ***Increased turgidity of guard cells allow opening of stomata.***

4. ***Water from the leaves (trapped in intercellular space inside the parenchyma tissue within the leaves) pass to the external environment through the opened up stomata.***



The more schematic drawing is:



Theories explaining Mechanism of Stomatal transpiration

A. Sugar Concentration Theory

This is the old theory, and according to it, during the daytime, guard cells perform photosynthesis and produce sugar (glucose) in it. Due to this,

there is a **decrease in water potential in the guard cells**, which let the water enter (**endosmosis**) it from nearby epidermal cells. This results in turgidity of the cells, which bulge outward due to their thinner outer walls—resulting in the opening of the pore.
During the night time, when no photosynthesis occurs, there is no sugar (glucose) formation in them, and guard cells lose their water content due to **exosmosis**(water goes out), resulting in no turgidity of guard cells which become flaccid, resulting in the closure of stomata.

The objection to sugar concentration theory

1) Sugar formation is less in guard cells.
2) It is not confirmed that guard cells have photosynthetic activity as their chloroplasts do not have much strength for photosynthesis.
3) In some plants, stomatal pores remain open during nighttime also.

B. Starch ⇌ Sugar Conversion Hypothesis

1. This theory was formulated in 1923 by J.D Sayre and modified by Steward in 1964.
2. Photosynthesis occurs in light by using CO2 present in the intercellular spaces. Due to this H+ concentration of cell sap decreases, resulting in increased pH of the guard cell.
3. High pH favours the formation of glucose-1- phosphate by the activity of the enzyme phosphorylase. This glucose-1-phosphate is changed to glucose-6-phosphate and finally to glucose and phosphate.
4. This glucose and phosphate increase the concentration of cell sap.
5. This concentrated cell sap decreases the water potential of the guard cells. Due to which there is the movement of water into the guard cells from the surrounding cells, resulting in turgidity of the guard cells.
6. This allows the stomatal pore to open.
7. At dark, there is no photosynthesis, resulting in a decrease of pH.
8. At low pH glucose is converted back into starch. This results in the high water potential of the guard cell.
9. Guard cells lose water to the surrounding cells causing the guard cells to become flaccid, and the pore closes.

C. K+ ion Concentration Theory (largely accepted theory)

Learn the steps by heart

Day time	Night time
During day time in presence of light the concentration of CO_2 decreases ↓ Malic acid produced within the guard cells of leaves ↓ Later dissociates into malate ions and H^+ ion ↓ K^+ ion exchange occurs from the subsidiary cells. (epidermal cells, adjoining the guard cells) ↓ Due to entry of K^+ ions and malate ions and malate ions osmotic pressure of the guard cells increased. ↓ Guard cell undergoes endosmosis (water enters into the guard cells) ↓ Whereby the Guard cells become turgid (swelled) ↓ Stomata open	In dark during night time the concentration of CO_2 increases ↓ Abscissic acid (ABA) released to stop the exchange of K^+ ions ↓ K^+ ions moved back into the subsidiary cells ↓ pH of the guard cells decreased ↓ Causing synthesis of starch in the guard cells ↓ Osmotic pressure of the guard cells decreased ↓ Water comes out of the guard cells i.e., exosmosis occurs. ↓ Stomata close

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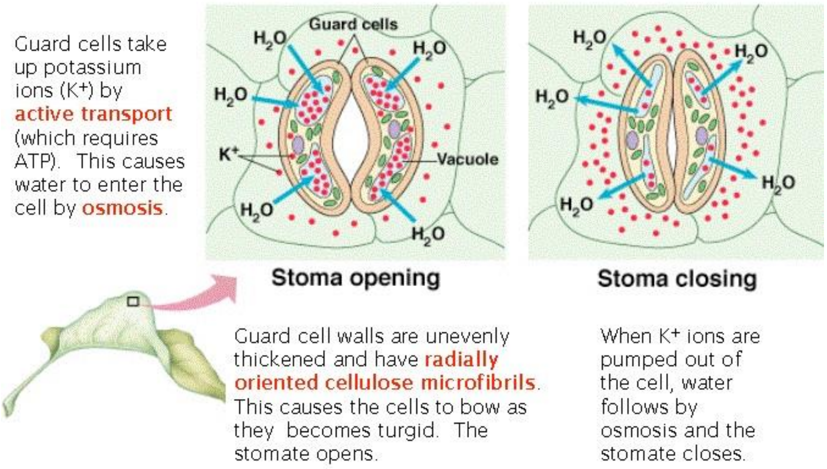
Control of Stomatal Opening and Closing



Guard cells take up potassium ions (K+) by **active transport** (which requires ATP). This causes water to enter the cell by **osmosis**.

Guard cell walls are unevenly thickened and have **radially oriented cellulose microfibrils**. This causes the cells to bow as they becomes turgid. The stomate opens.

When K+ ions are pumped out of the cell, water follows by osmosis and the stomate closes.

1. This theory was proposed by Levitt in 1974. This theory appears to be the most satisfactory mechanism.
2. During the daytime, starch present in the guard cells gets converted into malic acid in the presence of light.
3. This malic acid dissociates into malate anion and H+
4. H+ is transported to the nearby epidermal cells, and K+ are taken into guard cells.
5. There occurs an exchange of H+ and K+ ions which requires ATP.
6. Some chlorine, Cl– is also taken in to neutralize a small percentage of K+.

7. Increased K+ and malate ion in guard cells make them hypertonic *(in solution number 1 , solute concentration increases. So, this **solution number 1** becomes **hypertonic**. In another solution, say **solution number 2**, the solute concentration decreases, or it remains the same. This solution number 2 becomes **hypotonic** as compared to the solution number 1. Hypertonic solution is **more thick** and hypotonic solution is **less thick.** These terms are used in comparison.)* Due to which more water from adjacent cells is drawn into the cell, causing the cell to swell or become turgid (turgidity increases) . This causes opening of the stomatal pore.
8. The reverse happens at night. The K+ ion leaks out, thus reducing the turgidity of guard cells resulting in flaccid guard cells and stomatal pore closes.

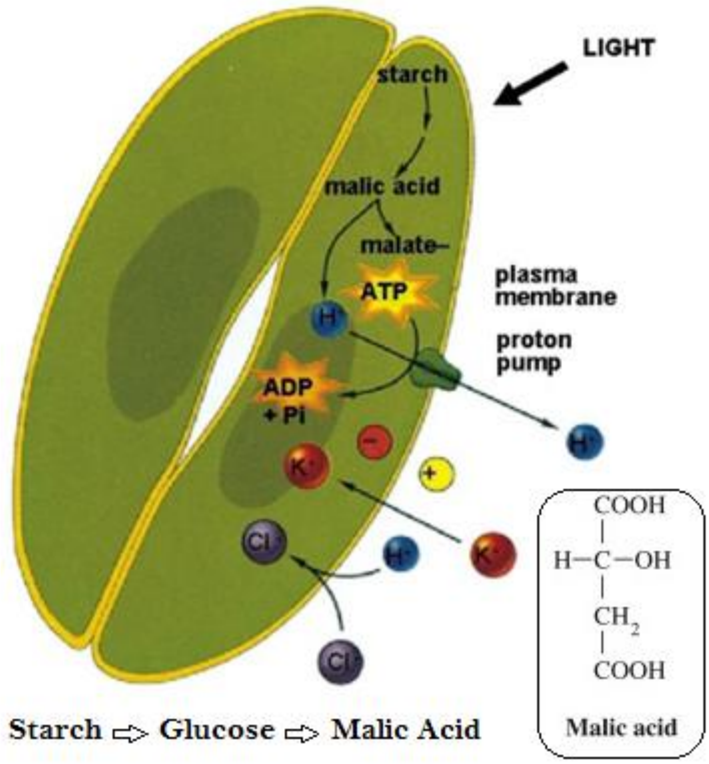


Fig: Stoma Showing Ion Exchange

Factors Affecting Stomatal Transpiration

1. **Atmospheric Humidity**– If outer air is humid, the rate of transpiration will decrease.
2. **Temperature**– With the increase in temperature, transpiration increases.
3. **Light**– Transpiration increases in light and decreases in the dark.
4. **Wind Velocity**– It increases the rate of transpiration
5. **Atmospheric Pressure**– Lowering atmospheric pressure increases the rate of transpiration.
6. **Soil Water**– The decrease of soil water decreases the rate of transpiration.